# Fish assemblages in rockweed *(Ascophyllum nodosum* (L.) Le Jolis) beds on the Atlantic Coast of Nova Scotia, Canada

Bénédikte Vercaemer, Melisa C. Wong and Monica A. Bravo

Science Branch
Coastal Ecosystem Research Division
Bedford Institute of Oceanography
Dartmouth, NS
B2Y 4A2

2018

**Canadian Technical Report of Fisheries and Aquatic Sciences 3249**

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

**Canadian Technical Report of Fisheries and Aquatic Sciences**

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

**Rapport technique canadien des sciences halieutiques et aquatiques**

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques*.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 3249

2018

# Fish assemblages in rockweed (*Ascophyllum nodosum* (L.) Le Jolis) beds on the Atlantic Coast of Nova Scotia, Canada

by

Bénédikte Vercaemer, Melisa C. Wong and Monica A. Bravo

Science Branch
Maritimes Region
Coastal Ecosystem Science Division
Fisheries and Oceans Canada
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, Nova Scotia,
B2Y 4A2

*Think Recycling!*

*Pensez à recycler*

© Her Majesty the Queen in Right of Canada 2018
Cat. No. Fs97-6/3249E-PDF ISBN 978-0-660-24700-7 ISSN 1488-5379

Correct citation for this publication:

Vercaemer, B., Wong, M.C., and Bravo, M.A. 2018. Fish assemblages in rockweed (*Ascophyllum nodosum* (L.) Le Jolis) beds on the Atlantic Coast of Nova Scotia, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3249: v + 34 p.

## Table of contents


Abstract ..... iv

Résumé ..... v

1. Introduction ..... 1

2. Materials and Methods ..... 2

2.1. Field site characteristics ..... 2

2.2. Survey of fish assemblages ..... 3

2.3. Age class ..... 4

2.4. Calibrations ..... 4

2.5. Species composition, richness and diversity ..... 5

2.6. Final data product for use in production model ..... 5

3. Results ..... 6

3.1. Characteristics of field sites ..... 6

3.2. Identification of fishes ..... 6

3.3. Age classes ..... 7

3.4. Sampling gear calibrations for fish abundance ..... 7

3.5. Gear calibrated species-specific fish density and habitat associations ..... 8

3.6. Calibrated YOY equivalent fish density per site ..... 9

4. Discussion and Conclusions ..... 10

Acknowledgements ..... 12

References ..... 13

Tables and Figures ..... 16

Appendix ..... 33

**Abstract**

Vercaemer, B., Wong, M.C., and Bravo, M.A. 2018. Fish assemblages in rockweed (*Ascophyllum nodosum* (L.) Le Jolis) beds on the Atlantic Coast of Nova Scotia, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3249: v + 34 p.

Field surveys were conducted in 2015 and 2016 at four sites on the Atlantic Coast of Nova Scotia to determine fish diversity and species-specific fish density and size in rockweed (*Ascophyllum nodosum*) beds and associated bare habitats. Fish assemblages were sampled biweekly during the day between May and September using visual snorkel transects. Data were calibrated to account for limitations to visual detection in the complex rockweed habitats using estimates of fish density from fyke nets. Diversity of fish assemblages (i.e., species richness, Shannon diversity index) was higher in rockweed beds than in associated bare habitats. Twenty-three species of fish and large decapods were detected, including commercial species such as Cod, Eel, Lobster, and Rock crab. Eighty percent of all fish captured were young of the year. Mean fish densities ranged from 0 to 1.37 individuals per $m^2$. Calibration ratios indicated that visual surveys detected most pelagic species but underestimated the density of most benthic fishes, while some species were not detected at all. This study provides new data that allows estimation of fisheries production by the DFO Fisheries Protection Program, and in general contributes to enhancing our understanding of nearshore ecosystem functioning.

**Résumé**

Vercaemer, B., Wong, M.C., and Bravo, M.A. 2018. Assemblages de poissons dans les lits d'ascophylle (*Ascophyllum nodosum* (L.) Le Jolis) sur la côte atlantique de la Nouvelle-Écosse, au Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3249: v + 34 p.

Des échantillonnages sur le terrain ont été effectués en 2015 et en 2016 dans quatre sites de la côte atlantique de la Nouvelle-Écosse afin de déterminer la diversité, la densité et la taille des poissons dans des lits d'ascophylle (*Ascophyllum nodosum*) entrecoupés d'habitats dénudés. Des assemblages de poissons ont été échantillonnés, pendant la journée, toutes les deux semaines, entre mai et septembre, à l'aide de transects visuels en plongée masque-tuba. Les données ont été étalonnées pour tenir compte des limites de détection visuelle dans les habitats complexes d'ascophylle en utilisant des estimations de l'abondance des poissons capturés avec des verveux. La diversité des assemblages de poissons (c.-à-d., richesse spécifique, indice de diversité Shannon) était plus élevée dans les habitats d'ascophylle que dans les habitats dénudés. Vingt-trois espèces de poissons et de grands décapodes ont été détectées, y compris des espèces commerciales comme la morue, l'anguille, le homard et le crabe vert. Quatre-vingt pour cent des poissons étaient juvéniles. Les densités moyennes des espèces variaient de 0 à 1,37 individus par $m^2$. Les rapports d'étalonnage ont indiqué que les relevés visuels détectaient la plupart des espèces pélagiques, mais sous-estimaient la plupart des poissons benthiques, alors que certaines espèces n'ont pas du tout été détectées. Cette étude apporte de nouvelles données qui permettent l'estimation de la production halieutique par le Programme de protection des pêches du MPO et, de façon générale, contribue à l'amélioration de notre compréhension du fonctionnement de l'écosystème côtier.

## 1. Introduction

In the Canadian Maritimes, the majority of rocky shore macroalgae (i.e. Fucales and Laminariales) biomass is concentrated on approximatively 4,000 km of coastline that is spared winter ice scour. This mainly includes the Eastern and South shores of Nova Scotia and the Bay of Fundy (Ugarte et al. 2010, Merzouk and Johnson, 2011). Sheltered rocky shores with little wave and wind exposure are dominated by the brown macroalgae *Ascophyllym nodosum* (common name rockweed) in the mid-intertidal to shallow subtidal zone. *A. nodosum* attaches to the rocky substrate by a long-lived holdfast and forms extensive and dense beds, often interspersed with other macroalgae species (*Fucus spp.*, red algae) and patches of bare bottom. Rockweed beds are highly productive, producing 0.61 to 2.82 kg dry weight per $m^2$ per year in Nova Scotia (Cousens 1984). Sharp and Semple (1991) reported a range of 4-18 wet kg per $m^2$ in their Rockweed stock assessment for southwest Nova Scotia. Rockweed beds can form extensive canopies that provide food resources and habitat for a variety of birds, fishes and invertebrates. They also provide ecosystem services such as primary production, fisheries maintenance, shoreline protection, carbon storage and nutrient cycling (Vadas et al. 2004, Vandermeulen 2013 and references within). With its floating three-dimensional branching structure, *A. nodosum* provides invertebrates and fish with a refuge from predation during high tide. During low tide, the fronds offer fauna protection from heat, light and desiccation by draping over tide pools and the sediment (Bertness et al. 1999, Gullo 2002).

In addition to these ecosystem services, *A. nodosum* has been commercially harvested in the Canadian Maritimes since the late 1950s to extract phycocolloid alginates, bio-stimulants for crops and animal feed supplements (Ugarte and Sharp 2012, Seeley and Schlesinger 2012). The bulk of the landings originate from the south western shore of Nova Scotia, mostly Lobster Bay, where rockweed biomass can reach 8-12 wet kg $m^{-2}$ (DFO 2013).

Similar to seagrasses in soft bottom sediments, canopy forming macroalgae such as rockweed are important habitats for nearshore foraging birds, fish and invertebrates in the rocky intertidal and subtidal. Knowledge of nekton assemblages in these habitats is necessary to fully understand the ecosystem functioning of nearshore ecosystems. Furthermore, knowledge of fish and crustacean assemblages in productive nearshore habitats such as rockweed beds is essential to inform policy, conservation and management strategies. In Canada, information of nearshore fish assemblages is particularly valuable to inform decision making associated with the DFO Fisheries Act amendments (2012). The Act includes provisions that manage threats and prohibits serious harm to the ongoing productivity of commercial, recreational, and aboriginal

(CRA) fisheries. A recent model framework allows estimates of fisheries productivity in data-poor situations, such as the nearshore (Wong and Dowd 2016). DFO Fisheries Protection Program is interested in evaluating nearshore fisheries productivity for rocky shores, yet data required for the model framework are limited. Here we aim to quantify fish abundance and assemblage structure in rockweed beds to improve our general understanding of coastal fish ecology and to contribute towards departmental decision making. Specifically, we (1) determined the density, diversity, and size distribution of fishes and large decapods using visual snorkel surveys in several rockweed beds on the Atlantic coast of Nova Scotia, and (2) calibrated the data to account for sampling biases relative to fixed fishing gear that sampled a known area (i.e., blocked fyke net). These data were used as model inputs to determine fish production derived from rockweed habitats using the model framework of Wong and Dowd (2016, 2017).

## 2. Materials and Methods

### 2.1. Field site characteristics

Nekton (i.e., fish and large decapods) assemblages were surveyed in four *Ascophyllum nodosum* beds on the Atlantic coast of Nova Scotia, Canada. Two sites were located on the Eastern shore (Mushaboom and East Jeddore) and two were on the South shore (Covey's Point and Thomas Raddall) (Figure 1). Sampling was conducted in July-August 2015 and May-September 2016. One site (Thomas Raddall) was only surveyed in 2015 while the remaining three sites (Mushaboom, East Jeddore and Covey's Point) were sampled in both years (Table 1).

To characterize vegetation cover and canopy height, a 0.5 x 0.5 m quadrat was placed haphazardly on the bottom near the beginning and end of each transect used to sample the fish assemblages (see below). Percent cover of *A. nodosum* and *Fucus spp.* were estimated as well as the species and percent cover of epiphytes fouling the *A. nodosum*. Canopy height was determined within each quadrat by extending the fronds to their maximum height and measuring the height of the tallest ~80%. Additionally, wet and dry biomass of all algal vegetation was determined in July 2015 at each site. To do so, eight 0.5 x 0.5 m quadrats were placed haphazardly at least 5 m apart through the rockweed bed and 2 m away from the bed edge, and all macroalgae were collected. Macroalgae were sorted into *A. nodosum* and *Fucus spp.* and wet biomass determined. Dry biomass was determined for four quadrats per site by drying a subsample at 60°C for 48h. The relationship between wet and dry biomass was determined using a linear regression.

Bottom water temperature was continuously measured using data loggers (HOBO Tidbits, Onset Computer Corporation, Bourne, MA, USA) deployed in the rockweed

beds. Temperature and salinity measurements were also conducted on each survey day with a hand-held YSI 30 (YSI Inc., Yellow Springs, Ohio, USA).

### 2.2. Survey of fish assemblages

Fish assemblages at each site were surveyed bi-weekly (every two weeks) during the day at mid to high tide using visual snorkel transects. Individual observers snorkelled transects that were approximately 100 m long x 1 m wide. At the mid-point of each transect (~50 m) a GPS waypoint was recorded so that data could be separated into two 50 m sections. Four to six replicate transects were conducted in parallel to each other and located >10 m inside the rockweed bed to avoid any edge effect. Transects were separated by at least 5 m. At Mushaboom, two transects were conducted consecutively because the width of the rockweed bed was narrow. Transects varied in distance for each survey according to terrain, wind conditions and currents, although the aim was 100 m. All transects were performed using a GPS (Garmin GPSmap 62stc, Garmin International Inc., Olathe, KS) with tracks recorded, from which the duration and speed of the observer was later determined.

Transect surveys were conducted to have the best detectability of species possible. Transect width was maintained at 1 m because detection of small fish was found to decline substantially beyond this distance in densely vegetated habitats (Wong and Bravo pers. obs.). The visual surveys were performed when water clarity was high, avoiding periods after rainfall events when colored dissolved organic matter and suspended sediments reduced clarity. To enhance detection of small and cryptic species (e.g., sticklebacks, juvenile cod), trained observers slowly swam on the surface at 0.10 - 0.16 m $s^{-1}$, adjusting swimming speed depending on the currents, rockweed density and canopy height. The top of the canopy was at times gently manipulated to observe canopy-dwelling species. The mean area sampled was similar for all field sites (Table 1) and, when carefully calculated from the recorded tracking information, was higher than the 100 $m^2$ anticipated (150-170 $m^2$). Preliminary analysis indicated no relationship between species richness and area sampled when area sampled was greater than 50 $m^2$. The fish abundance data from the two sections of each transect were subsequently pooled.

All benthic and pelagic fish and large decapods (e.g., crabs and shrimps) were identified, counted and total length estimated *in situ*. Additionally, each fish observation was associated with the sediment type, either vegetated and dominated by rockweed, or bare sediment. Bare sediments were typically interspersed within the rockweed beds and were defined as unvegetated patches consisting of boulders, cobbles and gravel

interspersed with sand and mud sediments. Data were also collected while swimming to the start of a new transect when possible, and were recorded in the same fashion (i.e. GPS coordinates, fish species, abundance, length, and habitat).

### 2.3. Age class

Data input for the fish production model of Wong and Dowd (2016) requires species-specific abundance per area (number of fish per $m^2$) in one age class from field surveys. In most cases, fish length was estimated during the surveys and age class was determined using length-age information from the regionally appropriate literature (Table 2 and Wong et al. 2016). In the very few cases where length could not be estimated, the most abundant age class for that species at that particular site was attributed for that particular fish. For most species, the majority were Young Of the Year (i.e., less than one year old, hereafter YOY). If a fish was not YOY, the age class was identified and the YOY equivalent was back calculated (Wong and Dowd 2016) when required for model input (see below).

### 2.4. Calibrations

To ensure that the detection of fish during visual surveys was optimal and the entire fish assemblage present was surveyed, a habitat appropriate sampling gear calibration method was developed at one site (East Jeddore) in the rockweed bed. No calibration was done for fish densities recorded in bare sediment as visual detection was satisfactory.

The calibration method consisted of comparing estimates of species-specific fish density determined from the visual surveys with those from unbaited fyke nets. The fyke net aimed to sample fish in a known area by allowing fish to swim inside the sample area at high tide, at which time the area was blocked off using nets. As the tide dropped, fish in the fenced off area were forced to swim into a trap which was collected at low tide. The fyke net system used (Figure 2) consisted of a chamber (i.e., a central trap with four frames tapering to a cod end) and wings that extended on either side to midway on the shore (top of the intertidal zone where fish were expected). The fyke net characteristics were as follows: mesh 6.35 mm, chamber (with cod end) of 4.5 m length consisting of one opening frame 1 x 1 m and four trap frames 0.8 m x 0.8 m, and two leader wings 1.5 m high x 20 m long. The last 5 m of the leader wings were angled inward to the opening frame. The leader wings were set during low tide to be 10 m

apart, perpendicular to the shore line, and supported by five poles each. The chamber was only attached to the opening frame at high tide. The exact location of each pole was recorded at each deployment using a GPS (Garmin GPSmap 62stc, Garmin International Inc., Olathe, KS) and used to calculate the area of the rockweed bed sampled (Garmin Base Camp, Garmin International Inc., Olathe, KS). The fyke net was deployed bi-weekly in July and August 2016 (n=8), fencing off an area of 168 to 208 $m^2$.

The captured fish were removed from the chamber and placed into bins filled with water, identified to species, counted and measured (total length) prior to release.

Fish density estimated from the fyke net samples were determined for each replicate as the number of fish divided by the area sampled. Calibration ratios between the two sampling types (i.e. fyke net and visual snorkel survey) were determined by dividing species-specific mean density estimated from the fyke net by mean density estimated from visual surveys. This calibration was implemented across all sites. Fish density data were not calibrated for day-night differences.

### 2.5. Species composition, richness and diversity

Species-specific fish density calibrated for sampling gear differences was calculated for each visual survey at each site as the number of fish per transect (i.e. corrected for gear differences, see above section 2.4.) divided by the area sampled. Diversity was measured as species richness (number of species per transect) and by the Shannon diversity index (H):

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

where S is species richness and $p_i$ is the proportion of the total abundance made up of the $i^{th}$ species. Species richness and Shannon diversity were computed using the vegan package in R version 3.5.

### 2.6. Final data product for use in production model

We conducted the gear calibration to account for the effect of dense vegetation on visual detection probabilities. We further adjusted the data prior to its use in the fish production model by determining the YOY equivalents for species where individuals older than YOY were sampled. These data are presented in the Appendix but are not

discussed in detail here. Rather, the focus of this study is on the gear calibrated data only.

## 3. Results

### 3.1. Characteristics of field sites

The field sites (Table 1) consisted of rockweed beds typical of those on the Atlantic shores of NS, although more extensive beds are found in southwest NS and the Bay of Fundy. The beds were located in shallow waters, with a mean depth at high tide of 1-1.5 m. Rockweed fronds were usually exposed at mean low tide.

Mean monthly water temperatures ranged from 7.5 to 19.9°C, peaking towards the end of August at all sites in both years (Figure 3). The exception was at Thomas Raddall which tended to be cooler by ~2°C degrees across the year. Salinity was more variable and on average lower for the Eastern shore sites (Mushaboom, East Jeddore) (27.5 psu ± 3.1 SD) than the South shore sites (Covey's Point, Thomas Raddall) (29.9 psu ± 0.8 SD) (Table 1).

Bare bottom (e.g., rocks, gravel, mud/sand) patches were interspaced within the rockweed beds at all sites. The average rockweed canopy height was similar among sites (50-55 cm), with the exception of Thomas Raddall where canopy height was ~80 cm (Figure 4A). Macroalgae cover (%) was high and consisted of at least 50% rockweed at all field sites. Covey's Point was the most diverse in terms of additional macroalgae and epiphytic species (Figure 4B). In some instances, up to 50% of *Fucus spp.* identified in a quadrat was epiphytic on *A. nodosum* thalli (Bravo pers. obs.). The total macroalgal biomass varied from 10.7 to 15.2 wet kg $m^{-2}$ or 2.5 to 4.7 dry kg $m^{-2}$. *Fucus spp.* represented a very small portion of the biomass, to a maximum of 5% of the total wet weight at Thomas Raddall (Figure 4C-D). The ratio of dry weight (DW) to wet weight (WW) was calculated for *A. nodosum* as: DW = 0.307 * WW (n=16, $R^2$=0.98).

### 3.2. Identification of fishes

Some species, such as those in the families Gadidae (cod) and Gasterosteidae (sticklebacks), were difficult to resolve to the species level *in situ*. The sampling gear calibration conducted in 2016 with the fyke net allowed the species identification to be further refined. The ratio between the two Gadidae species present (Cod:Tomcod; 58:42) calculated from the fyke net data (Table 3) was applied to each replicate visual transect when species could only be identified as Gadidae. The ratio between the three

Stickleback species Fourspine: Ninespine: Threespine was determined to be 90.4: 6.2: 3.4, but owing to the small number of unknown Stickleback species per transect, all species identified only to Gasterosteidae were attributed to be the dominant Fourspine stickleback.

Fish identified as Osmeridae during the surveys were classified as Smelt according to their life history and knowledge of the sites. Eighteen fish could not be identified further and were removed from the dataset. A total of 8732 fish were identified in a total of 241 visual snorkel surveys, while 309 fish were collected in a total of 8 fyke net samples.

### 3.3. Age classes

The fish and crustaceans observed were predominately YOY, and the proportion of YOY for the total of each species sampled was >75% for Cod, Grass shrimp, Herring, Mackerel, Pipefish, Pollock, Sand lance, Silverside, Smelt, Tomcod and White hake (Table 4). Cunner, Sticklebacks, and Winter flounder were mostly Y2 (63, 52, and 64% of the total sample for each species, respectively). Eels observed as Y2 were spending their first year in the inshore, while 75% of the eels observed were >Y10. Species not observed as YOY included Jonah crab and Lobster. A wide range of sizes were observed for most species (Figure 5) which translated into multiple age classes for species such as Cunner, Green crab and Rock gunnel.

### 3.4. Sampling gear calibrations for fish abundance

Estimates for fish density from the fyke nets showed that several species were higher in density relative to estimates from the visual snorkel surveys (Figure 6). A calibration ratio was applied when the density estimates from fyke net samples for a particular species was higher than those from visual surveys, indicating low visual detection probability for that species. Calibration ratios were therefore applied to density estimates of five species: Cod, Eel, Fourspine stickleback, Green crab and Mummichog (Table 3). In addition, when species were sampled with the fyke net but were not detected in visual surveys at the calibration site, their respective mean fish density calculated with the fyke net samples was added to the densities calculated from visual surveys. This was the case for only four species: Grass shrimp, Grubby sculpin, Pipefish and Tomcod. In other words, these species, while present in rockweed beds, were particularly difficult to detect with visual surveys and the calibration allowed correction for their cryptic nature. Outside of the calibration site (i.e., East Jeddore), this

addition to observed densities was only done when these four species had been detected in rockweed habitat in at least one visual survey during the study period. Therefore, this calibration was done for Tomcod and Grass shrimp at Mushaboom, East Jeddore and Covey's Point, for Pipefish at Mushaboom and Covey's Point, and for Grubby sculpin at Mushaboom, but not at Thomas Raddall where none of those species had been detected. Finally, no adjustment was made for the ten species not captured in the fyke net: Jonah crab, Lobster, Pollock, Rock crab, Rock gunnel, Sand lance, Smelt, Threespine stickleback, White hake and Winter flounder.

Ninespine stickleback and Sand shrimp were captured in very small numbers in the fyke net, but not during any visual survey during the calibration period (Table 3). Consequently, no adjustment was made for those species. Similarly, for three pelagic species, Herring, Mackerel and Silverside, and for Cunner, no adjustment was made due to their absence or very small sample size in the fyke net samples. These species were easily identified during the visual snorkel surveys and did not need correction for limited detection probability.

### 3.5. Gear calibrated species-specific fish density and habitat associations

Eighteen species of fish and five species of large decapods were recorded during the visual surveys conducted in rockweed beds or associated bare habitats at the study sites (Table 5). Of these, twelve species hold commercial fishery status in the Canadian Maritime provinces, including Cod, Eel, Herring, Lobster, Mackerel, Pollock, Rock crab, Sand lance, Silverside, Tomcod, White Hake and Winter flounder. All the species recorded in the survey are predominantly found inshore as YOY although some species such as Pollock, Cod, White hake, Silverside and Pipefish often migrate offshore as adults in the winter (Rangeley and Kramer 1995, Wong et al. 2016).

Species richness (gear calibrated) was consistently higher in rockweed beds (ranging from 2.15 at Thomas Raddall to 5.96 at Mushaboom) relative to bare habitats (from 0.61 at East Jeddore to 1.08 at Covey's Point) (Figure 7A). The Shannon diversity index was also consistently higher in rockweeds beds (from 0.31 at Thomas Raddall to 0.98 at Mushaboom) compared to bare habitats (from 0.06 at East Jeddore to 0.13 at Covey's Point) (Figure 7B).

Species-specific gear calibrated fish densities are presented for each of the field sites and for both rockweed beds and bare habitat in Figure 8. Calibrated YOY equivalent densities are presented only in the Appendix. Many of the species were observed mostly in the vegetated portions of the rockweed beds, although some species were observed in both habitat types. Benthic Lobster, crabs and fishes (e.g., Grubby sculpin

and Winter flounder) were routinely observed in both rockweed and bare sediment habitats. Pelagic species found higher in the water column showed high affinity with rockweed beds relative to bare areas (e.g., Herring, Silversides). Some species were observed at only one or two field sites and were strongly associated with rockweed beds (e.g., Jonah crab, Mummichog, Pollock), except for Rock crab which were observed in both habitats at Mushaboom and only in the bare habitat at Covey's Point (Figure 8). Lobster was only observed at Thomas Raddall, and in both habitats.

The four species that were not well detected in visual transects during the calibration exercise were Grass shrimp, Grubby sculpin, Pipefish and Tomcod. Grass shrimp are hard to see due to their transparent coloration but were present at all sites from June-September, except at Thomas Raddall. Grubby sculpin often rest on the bottom and are well camouflaged, making them difficult to see among the vegetation, but were detected at Mushaboom. Pipefish are difficult to see due to their shape, coloration and position within the vegetation but were detected at Covey's Point and at Mushaboom during visual surveys. Tomcod are also hard to identify as a species due to their coloration and skittish nature but they were detected at all sites as Gadidae and then confirmed as Tomcod with the fyke net calibration.

Species-specific fish densities in rockweed beds were typically higher in 2015 relative to 2016 at the three sites surveyed in both years (Mushaboom, East Jeddore and Covey's Point), with the exception of a few species such as Mummichog, Threespine stickleback, Tomcod and Winter flounder (Figure 9). This inter-annual variability highlights the importance of multi-year surveys. Species-specific densities also varied on a monthly basis. For example, in 2016, Cod and Tomcod were only present in rockweed beds in May and June and species such as Herring were only present only in August and September (Figure 10). This highlights the importance of surveying fish assemblages not only over several years but also over seasons.

### 3.6. Calibrated YOY equivalent fish density per site

Species-specific mean densities that were calibrated for gear differences and are representative of YOY equivalents were pooled across sites for use in the fish production model. These data are shown in Table 6 and as figures in the Appendix. Mean densities ranged from 0 to 1.37 individuals per $m^2$. The gear calibrated YOY equivalent fish densities presented here were used as input in a new model of fish production (Wong and Dowd 2017).

## 4. Discussion and Conclusions

This report provides previously unavailable data of fish assemblage structure and species densities in *Ascophyllum nodosum* beds on the Atlantic coast of Nova Scotia. Rockweed biomass at our field sites were within the range of estimates for more extensive beds that are commercially harvested in southern NS. Our results show that rockweed beds are important habitat for a wide variety of fishes, including several commercial fishery species. We also found that a high proportion of the fish assemblages in rockweed beds are comprised of YOY and juveniles. Rockweed beds are clearly important for fisheries production and, with the exception of the more exposed Thomas Raddall site, fish density and fish assemblages were similar among the study sites.

The fish and crustacean species observed in our study were similar to those observed in rockweed beds in other regions of Nova Scotia (Black and Miller 1991, Schmidt et al. 2011, Kay et al. 2016). However, we typically observed higher abundances for most species compared to these other studies. We also observed several unique species not recorded in rockweed beds before, including Herring, Sand lance, Silverside, and Smelt. The abundance of these schooling species may be highly variable among sample periods and years. Previous studies conducted on the South shore of NS found that some fishes (e.g., White hake, Fourspine stickleback) were regularly abundant where substrate was homogeneous (O'Connor, 2008), as observed in our study. While Pollock was the dominant species observed in rockweed beds in the Bay of Fundy (Corrigan 2003), it was only detected sporadically at East Jeddore in our study.

Although fish species diversity and richness in rockweed beds are similar to that observed in eelgrass (*Zostera marina*) in the same intertidal and shallow subtidal regions of NS, it is worth noting some differences. Cod, Mackerel, Mummichog and Smelt were only observed in rockweed beds and, by contrast, Killifish, Sea raven, Snailfish, Scad and Sand shrimp were only observed in eelgrass beds. Additionally, Green crab, Grubby sculpin, Rock crab, Lobster, Sticklebacks and other species associated with the sea bottom were observed in both rockweed and eelgrass beds, but tended to be present at a lower density in rockweed beds (Wong et al. 2016). Only Cunner, Eel and Sand lance were observed in rockweed beds at higher densities compared to eelgrass beds (Wong et al. 2016). Our study found that the density of most fishes was higher in rockweed than associated bare sediments, which has also been observed in other studies and in eelgrass beds of Atlantic Canada (Schmidt et al. 2011, Wong and Dowd 2016).

We used non-lethal and cost-effective visual surveys to estimate species-specific fish densities in rockweed habitats. Visual surveys can be biased particularly by limited

detection probability of certain species. We attempted to account for these biases by calibrating the data using estimates from fyke nets, assuming that these nets provide more accurate estimates of fish abundance than visual detection. The gear calibration exercise allowed calibration ratios and densities to be developed for nine benthic species. Pelagic species were not adequately captured by the fyke nets yet were adequately sampled during visual surveys, so no calibration ratios were necessary for these. We recognize that the capture efficiency of the fyke net would have differed for each species, yet were unable to account for this. Alternative sampling gear such as benthic trawls, as used to sample seagrass fish assemblages (Wong et al. 2016), could not have been deployed at the field sites because of the large boulders and cobbles. Also, popnets were found to be difficult to deploy in the rockweed beds on initial testing, and were inappropriate for the spatial variability and low densities of fish observed at our sites. Gill nets could have been useful to sample pelagic fishes yet would have excluded large decapods and resulted in high fish mortality. For these reasons, we chose to utilize visual transects with calibration via fyke nets. This complementary set of sampling gears allowed us to adequately sample both pelagic and benthic fishes that are difficult to capture with only one type of sampling gear.

Some species of nearshore fishes and decapods are primarily nocturnal. Of the species observed in our assemblages, Eel, Herring, Silverside, Smelt, Tomcod, Rock crab and Green crab have been shown to be more active at night than during the day in seagrass beds (McCleave and Fried 1975, Mattila et al. 1999, Wong et al. 2016). However, studies that examine day-night differences in rockweed fish assemblages have shown inconsistencies: Corrigan (2003) found that most pelagic fish were captured at night in the Bay of Fundy while Schmidt et al. (2011) did not detect differences in macrofaunal assemblages between day and night on the Eastern shore of NS. In our study, we were unable to evaluate day-night differences, yet could do so in the future using the fyke net.

In summary, we present some of the first data of fish assemblages in rockweed beds on the Atlantic coast of Nova Scotia. Species-specific fish density and diversity were estimated with visual snorkel transects conducted biweekly during the day between May and September. We detected twenty-three species of fish and large decapods, including commercial species such as Cod, Eel, Lobster, and Rock crab, and attempted to provide the most accurate estimates of fish density using calibrations that accounted for limitations to visual detection. This study provides new data that enhances understanding of nearshore fish ecology and can guide decision making by the DFO Fisheries Protection Program.

**Acknowledgements**

We would like to thank Matt Beyer, Emily Blacklock, Anna MacDonnell, Kristian Sacco, Ciara Willis and Vicky Yaroshewski for their field support. Funding was provided by DFO Strategic Program for Ecosystem-based Research and Advice (SPERA).

**References**


Bertness, M.D., Leonard, G.H., Levine, J.M., Schmidt, P.R. and Ingraham, A.O. 1999. Testing the relative contribution of positive and negative interactions in rocky intertidal communities. Ecology 80: 2711-2726.

Black, R. and Miller, R.J. 1991. Use of the intertidal zone by fish in Nova-Scotia. Environ. Biol. of Fish. 31: 109-121.

Cousens, R. 1984. Estimation of annual production by the intertidal brown alga *Ascophyllum nodosum* (L.) Le Jolis. Bot. Mar. 27: 217-227.

Corrigan, S.E. 2003. Fish communities in intertidal rockweed (*Ascophyllum nodosum*) beds in the Bay of Fundy. Thesis (M.Sc.), University of New Brunswick, Saint John, NB, Canada, 64 p.

DFO. 2013. Assessment of information on Irish moss, rockweed, and kelp harvests in Nova Scotia. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/004.

Fritz, E.S. and Garside, E.T. 1975. Comparison of age composition, growth, and fecundity between two populations each of *Fundulus heteroclitus* and *F. diaphanus* (Pisces: Cyprinodontidae). Can. J. Zool. 53: 361-369.

Gullo, A.M. 2002. The value of rockweed (*Ascopyllum nodosum*) as habitat for tidepool fishes. Thesis (M.Sc.), University of Maine, Orono, ME, USA, 90 p.

Kay, L., Eddy, T.D., Schmidt, A.L. and Lotze, H.K. 2016. Linking canopy structure and community composition of rockweed habitats in Atlantic Canada. Mar. Biol. 163: 251.

Mattila, J., Chaplin, G., Eilers, M.R., Heck, Jr., K.L., O'Neal, J.P. and Valentine, J.F. 1999. Spatial and diurnal distribution of invertebrate and fish fauna of a *Zostera marina* bed and nearby unvegetated sediments in Damariscotta River, Maine (USA). J. Sea Res. 41: 321-332.

McCleave, J.D. and Fried, S.M. 1975. Nighttime catches of fishes in a tidal cove in Montsweag Bay, Wiscasset, Maine. Trans. Am. Fish. Soc. 104: 30-34.

Merzouk, A. and Johnson, L.E. 2011. Kelp distribution in the northwest Atlantic Ocean under a changing climate. J. Exp. Mar. Biol. Ecol. 400: 90-98.

O'Connor, S.H. 2008. Relationships between juvenile fish assemblages and the physical features of bays along the Atlantic coast of mainland Nova Scotia, with implications for coastal Marine Protected Areas. Thesis (M.Sc.), Acadia University, Wolfville, NS, Canada, 141 p.

Ugarte, R.A., Craigie, J.S. and Critchley, A.T. 2010. Fucoid flora of the rocky intertidal of the Canadian Maritimes: implications for the future with rapid climate change. *In*: Seaweeds and their role in globally changing environments. Cellular origin, life in extreme habitats and astrobiology, vol. 15. Edited by A. Israel, R. Einav and J. Seckbach. Springer, Netherlands, pp 69-90.

Ugarte, R.A. and Sharp, G. 2012. Management and production of the brown algae *Ascophyllum nodosum* in the Canadian Maritimes. J. Appl. Phycol. 24: 409-416.

Rangeley, R.W. and Kramer, D.L. 1995. Use of rocky intertidal habitats by juvenile pollock *Pollachius virens*. Mar. Ecol. Prog. Ser.126: 9-17.

Schmidt, A.L., Coll, M., Romanuk, T.N. and Lotze, H.K. 2011. Ecosystem structure and services in eelgrass *Zostera marina* and rockweed *Ascophyllum nodosum* habitats. Mar. Ecol. Prog. Ser. 437: 51-68.

Seeley, R.H. and Schlesinger, W.H. 2012. Sustainable seaweed cutting? The rockweed (*Ascophyllum nodosum*) industry of Maine and the Maritime Provinces. Ann. N. Y. Acad. Sci. 1249: 84-103.

Sharp, G., and Semple, R. 1991. An assessment of *Ascophyllum nodosum* resources in Scotia / Fundy 1990. Canadian Atlantic Fisheries Scientific Advisory Committee Research Document, 91/52.

Vadas, R.L., Wright, W.A. and Beal, B.F. 2004. Biomass and productivity of intertidal rockweeds (*Ascophyllum nodosum* LeJolis) in Cobscook Bay. Northeast. Nat. 11: 123-142.

Vandermeulen, H. 2013. Information to support assessment of stock status of commercially harvested species of marine plants in Nova Scotia: Irish moss, rockweed and kelp. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/042. vi + 50 p.

Wong, M.C. and Dowd, M. 2016. A model framework to determine the production potential of fish derived from coastal habitats for use in habitat restoration. Estuar. Coast. 39: 1785-1800.

Wong, M.C. and Dowd, M. 2017. Towards regional benchmarks of fish productivity in nearshore marine ecosystems: Model framework, habitat comparisons, and examination of regional data. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/078. vi + 47 p.

Wong, M.C., Dowd, M., Bravo, M.A., Giroux, C., Haverstock, A., Humble, M., MacFarlane, M., Roach, S. and Rowsell, J. 2016. Nekton in *Zostera marina* (eelgrass) beds and bare soft-sediment bottom on the Atlantic Coast of Nova Scotia, Canada: species-specific density and data calibrations for sampling gear and day-night differences. Can. Tech. Rep. Fish. Aquat. Sci. 3155: v + 40 p.

## Tables and Figures

Table 1. Description of field sites on the South and Eastern shores of NS sampled using snorkel visual surveys. Depth is at mean high tide.

| Site (Abbreviation) | Latitude | Longitude | Sampling periods | Depth (m) | Number of surveys | Mean area sampled ($m^2$) ± se | Mean percentage vegetation cover (%) ± se | Salinity (psu) mean ± SD (range) |
|---|---|---|---|---|---|---|---|---|
| Mushaboom (MB) | 44.85600 | -62.54472 | July 23-Aug 20, 2015<br>May 25-Sept 20, 2016 | 1 - 1.5 | 76 | 167.8 ± 5.8 | 73.65 ± 0.98 | 27.6 ± 3.4<br>(21.2-30.0) |
| East Jeddore (EJ) | 44.77676 | -63.00731 | July 20- Aug 21, 2015<br>May 24-Sept 19, 2016 | 1 - 1.5 | 65 | 147.7 ± 4.7 | 75.99 ± 1.76 | 27.4 ± 2.9<br>(19.0-30.2) |
| Covey's Point (CP) | 44.50241 | -64.11469 | July 24-Aug 18, 2015<br>May 27- Sept 21, 2016 | 1 - 1.5 | 87 | 149.9 ± 5.0 | 71.89 ± 1.03 | 29.8 ± 0.9<br>(27.6-31.0) |
| Thomas Raddall (TR) | 43.82743 | -64.87866 | July 22-Aug 19,2015 | 1 - 1.5 | 13 | 161.8 ± 9.5 | 79.58 ± 2.28 | 30.0 ± 0.2<br>(29.8-30.3) |

Table 2. Summary table of fish lengths sampled and length information used to determine age classes. Length is total length unless indicated otherwise. CW = carapace width, CL = carapace length. Modified from Wong et al. 2016.

| Common name | Scientific name | Length range in survey (mm) | Year classes observed | Corresponding size classes (mm) |
|---|---|---|---|---|
| American eel | *Anguilla rostrata* | 80-1000 | Y2, Y3, Y4, Y5, Y6, Y10, Y15, Y20 | ≤150, 200, 250, 325, 450, 700, 1000 |
| American lobster (CL) | *Homarus americanus* | 60-100 | Y4, Y5, Y6 | ≤65, 79, 100 |
| Atlantic cod | *Gadus morhua* | 50-200 | YOY, Y2, Y3 | 0+, 150, 220 |
| Atlantic herring | *Clupea harengus* | 50-100 | YOY, Y2 | 0+, 180 |
| Atlantic mackerel | *Scomber scombrus* | 150-300 | YOY, Y2, Y3 | 0+, 257, 301 |
| Atlantic silverside | *Menidia menidia* | 60-80 | YOY, Y2 | 0+, 81 |
| Atlantic tomcod | *Microgadus tomcod* | 57-63 | YOY, Y2 | 0+, 100 |
| Cunner | *Tautogolabrus adspersus* | 10-180 | YOY, Y2, Y3, Y4, Y5 | 0+, 70, 115, 155, 180 |
| Fourspine stickleback | *Apeltes quadracus* | 27-100 | YOY, Y2, Y3 | 0+, 30, 60 |
| Grass shrimp (CL) | *Palaemon sp.* | 8-19 | YOY, Y2 | 0+, 12 |
| Green crab (CW) | *Carcinus maenas* | 10-120 | YOY, Y2, Y3, Y4, Y5, Y6 | 0+, 31, 45, 60, 70, 80 |
| Grubby sculpin | *Myoxocephalus aenaeus* | 25-100 | YOY, Y2, Y3, Y4 | 0+, 65, 90, 120 |
| Herring | *Clupea harengus* | 50-100 | YOY, Y2, Y3 | 0+, 180, 215 |
| Jonah crab (CW) | *Cancer borealis* | 40-150 | YOY, Y2, Y3, Y4, Y5, Y6, Y7 | 0+, 14, 40, 66, 80, 97, 117 |
| Mummichog | *Fundulus heteroclitus* | 20-87 | YOY, Y2, Y3, Y4, Y5 | 0+, 45, 60, 75, 90 [1] |
| Ninespine stickleback | *Pungitius pungitius* | 28-64 | YOY, Y2 ,Y3 ,Y4 ,Y5 | 0+, 36, 46, 53, 65 |
| Pipefish | *Syngnathus fuscus* | 100-210 | YOY, Y2, Y3, Y4 | 0+, 175, 200, 300 |
| Pollock | *Pollachius virens* | 80 | YOY, Y2 | 0+, 200 |
| Rock crab (CW) | *Cancer irroratus* | 10-100 | YOY, Y2, Y3, Y4, Y5, Y6, Y7 | 0+, 14, 40, 66, 80, 97, 117 |
| Rock gunnel | *Pholis gunnellus* | 20-180 | YOY, Y1, Y2, Y3, Y4 | 0+, 70, 100, 120, 140 |
| Sand lance | *Ammodytes americanus* | 30-120 | YOY, Y2 ,Y3 | 0+, 91, 155 |
| Sand shrimp (CL) | *Crangon septemspinosa* | 5-9 | YOY, Y2, Y3, Y4 | 0+,10,14,17 |
| Smelt | *Osmerus mordax* | 40-110 | YOY, Y2, Y3 | 0+, 100, 127 |
| Threespine stickleback | *Gasterosteus aculeatus* | 35-49 | YOY, Y2, Y3 | 0+, 30, 60 |
| White hake | *Urophysis tenuis* | 100-150 | YOY, Y2 | 0+, 151 |

[1] Fritz and Garside, 1975

Table 3. Calibration data used to account for sampling biases from visual snorkel surveys. Densities and ratios were determined from the calibration exercise conducted at East Jeddore in July-August 2016 that compared mean fish densities estimated from fyke nets (FN) and snorkel transects (ST). Only values in bold were used to correct densities estimated in sorkel transects.

| Common name | Scientific name | Fyke Net | | Snorkel Transects | | FN:ST ratio |
|---|---|---|---|---|---|---|
| | | abundance | density (per $m^2$) | abundance | density (per $m^2$) | |
| American eel | *Anguilla rostrata* | 5 | 0.003487 | 2 | 0.000694 | **5.020628** |
| Atlantic cod | *Gadus morhua* | 2 | 0.00144 | 2 | 0.00085 | **1.694599** |
| Atlantic herring* | *Clupea harengus* | 2 | 0.001386 | 250 | 0.090783 | |
| Atlantic mackerel* | *Scomber scombrus* | 0 | NA | 18 | 0.00463 | |
| Atlantic silverside* | *Menidia menidia* | 0 | NA | 3 | 0.00141 | |
| Atlantic tomcod | *Microgadus tomcod* | 5 | **0.003673** | 0 | NA | |
| Cunner* | *Tautogolabrus adspersus* | 1 | 0.000692 | 11 | 0.004129 | |
| Fourspine stickleback | *Apeltes quadracus* | 124 | 0.087663 | 5 | 0.002012 | **43.56545** |
| Grass shrimp | *Palaemon sp.* | 62 | **0.042945** | 0 | NA | |
| Green crab | *Carcinus maenas* | 48 | 0.034165 | 17 | 0.00712 | **4.798244** |
| Grubby sculpin | *Myoxocephalus aenaeus* | 4 | **0.002821** | 0 | NA | |
| Mummichog | *Fundulus heteroclitus* | 46 | 0.032192 | 1 | 0.000437 | **73.65625** |
| Ninespine stickleback^ | *Pungitius pungitius* | 5 | 0.003484 | 0 | NA | |
| Pipefish | *Syngnathus fuscus* | 4 | **0.002547** | 0 | NA | |
| Sand shrimp^ | *Crangon septemspinosa* | 1 | 0.000601 | 0 | NA | |

* No calibration possible because the fyke net does not target these species

^ Species only caught with FN samples at East Jeddore but not seen during any visual surveys conducted in 2015-2016

Table 4. Abundance of fish per year class and proportion of fish surveyed from snorkel or swim transects that were YOY. Values are pooled across all sites and years.

| Common name | Scientific name | Abundance in Year class | | | | | | | | | | Total | Proportion YOY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | YOY | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y10 | Y15 | Y20 | | |
| American eel | *Anguilla rostrata* | | 4 | | | | | | 5 | 6 | 1 | 16 | 0 |
| American lobster | *Homarus americanus* | | 3 | 1 | | | | | | | | 4 | 0 |
| Atlantic cod | *Gadus morhua* | 232 | 2 | | | | | | | | | 234 | 0.991 |
| Atlantic herring | *Clupea harengus* | 874 | | | | | | | | | | 874 | 1 |
| Atlantic mackerel | *Scomber scombrus* | 23 | 1 | | | | | | | | | 24 | 0.958 |
| Atlantic silverside | *Menidia menidia* | 94 | | | | | | | | | | 94 | 1 |
| Atlantic tomcod | *Microgadus tomcod* | 144 | | | | | | | | | | 144 | 1 |
| Cunner | *Tautogolabrus adspersus* | 98 | 215 | 21 | 3 | 1 | | | | | | 338 | 0.290 |
| Fourspine stickleback | *Apeltes quadracus* | | 19 | 20 | | | | | | | | 39 | 0 |
| Grass shrimp | *Palaemon sp.* | 8 | | | | | | | | | | 8 | 1 |
| Green crab | *Carcinus maenas* | 95 | 98 | 154 | 199 | 171 | 133 | | | | | 850 | 0.112 |
| Grubby sculpin | *Myoxocephalus aenaeus* | 5 | 2 | 2 | | | | | | | | 9 | 0.556 |
| Jonah crab | *Cancer borealis* | | | 1 | 1 | 1 | | 2 | | | | 5 | 0 |
| Mummichog | *Fundulus heteroclitus* | 3 | 2 | | 1 | | | | | | | 6 | 0.500 |
| Pipefish | *Syngnathus fuscus* | 6 | 2 | | | | | | | | | 8 | 0.750 |
| Pollock | *Pollachius virens* | 2 | | | | | | | | | | 2 | 1 |
| Rock crab | *Cancer irroratus* | 1 | 1 | 3 | | | 1 | | | | | 6 | 0.167 |
| Rock gunnel | *Pholis gunnellus* | 1 | 2 | 3 | 4 | 1 | | | | | | 11 | 0.091 |
| Sand lance | *Ammodytes americanus* | 5097 | 436 | | | | | | | | | 5533 | 0.921 |
| Smelt | *Osmerus mordax* | 504 | 6 | | | | | | | | | 510 | 0.988 |
| Threespine stickleback | *Gasterosteus aculeatus* | | 3 | | | | | | | | | 3 | 0 |
| White hake | *Urophysis tenuis* | 3 | | | | | | | | | | 3 | 1 |
| Winter flounder | *Pseudopleuronectes americanus* | 1 | 7 | 3 | | | | | | | | 11 | 0.091 |
| **Total** | | **7191** | **803** | **208** | **208** | **174** | **134** | **2** | **5** | **6** | **1** | **8732** | **0.805** |

Table 5. Abundance of fish surveyed at four sites (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point, TR = Thomas Raddall). Visual surveys were either conducted by snorkeling (ST) or swimming to/from and between transects (SW). Number of replicate transects are indicated in brackets. Values are pooled across all replicate transects and years for each site. Total area sampled for snorkel transects were 8058, 7682, 7495, and 1942 $m^2$ at MB, EJ, CP, and TR, respectively. Total area sampled for swim transects were 2014, 743, 2683, and 50 $m^2$ at MB, EJ, CP, and TR, respectively. Densities are presented in Figure 8.

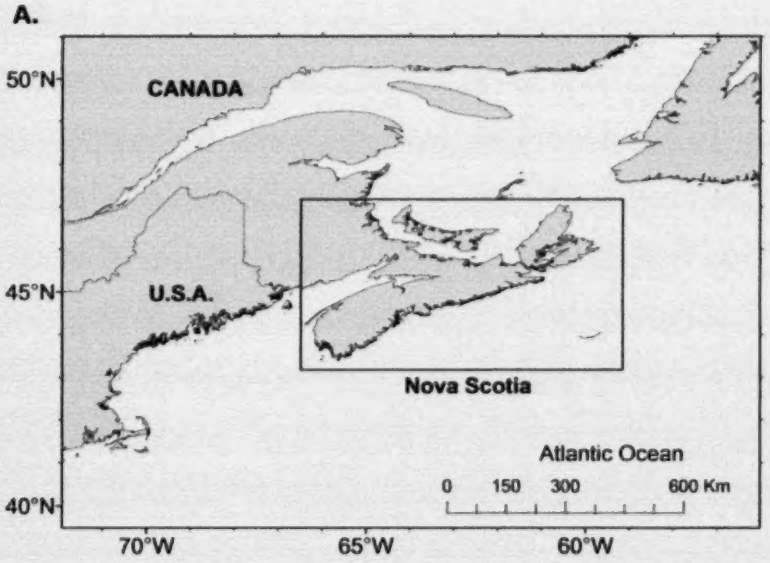
| Common name | Scientific name | MB | | EJ | | CP | | TR | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ST (48) | SW (28) | ST (52) | SW (13) | ST (50) | SW (37) | ST (12) | SW (1) | |
| American eel* | *Anguilla rostrata* | 1 | 1 | 8 | 3 | 1 | 1 | 1 | | **16** |
| American lobster* | *Homarus americanus* | | | | | | | 4 | | **4** |
| Atlantic cod* | *Gadus morhua* | 112 | 26 | 12 | | 64 | 14 | 6 | | **234** |
| Atlantic herring* | *Clupea harengus* | 399 | 1 | 360 | 111 | 1 | | | 2 | **874** |
| Atlantic mackerel* | *Scomber scombrus* | | | 19 | | 1 | 4 | | | **24** |
| Atlantic silverside* | *Menidia menidia* | | 31 | 3 | | 30 | | 10 | 20 | **94** |
| Atlantic tomcod* | *Microgadus tomcod* | 52 | 26 | 3 | | 49 | 14 | | | **144** |
| Cunner | *Tautogolabrus adspersus* | 78 | 19 | 55 | 12 | 135 | 19 | 20 | | **338** |
| Fourspine stickleback | *Apeltes quadracus* | 4 | | 31 | 4 | | | | | **39** |
| Grass shrimp | *Palaemon sp.* | 6 | | 1 | | 1 | | | | **8** |
| Green crab | *Carcinus maenas* | 336 | 6 | 225 | | 161 | 10 | 112 | | **850** |
| Grubby sculpin | *Myoxocephalus aenaeus* | 5 | 2 | 1 | | 1 | | | | **9** |
| Jonah crab | *Cancer borealis* | | | | | 1 | | 4 | | **5** |
| Mummichog | *Fundulus heteroclitus* | | | 6 | | | | | | **6** |
| Pipefish | *Syngnathus fuscus* | 1 | 4 | 1 | | 1 | 1 | | | **8** |
| Pollock* | *Pollachius virens* | | | 2 | | | | | | **2** |
| Rock crab* | *Cancer irroratus* | 5 | | | | 1 | | | | **6** |
| Rock gunnel | *Pholis gunnellus* | 4 | 2 | | | 4 | 1 | | | **11** |
| Sand lance* | *Ammodytes americanus* | 308 | 541 | 90 | | 2815 | 1779 | | | **5533** |
| Smelt | *Osmerus mordax* | 23 | 451 | 32 | 3 | 1 | | | | **510** |
| Threespine stickleback | *Gasterosteus aculeatus* | | | | | 1 | 2 | | | **3** |
| White hake* | *Urophysis tenuis* | | 1 | | | 1 | | 1 | | **3** |
| Winter flounder* | *Pseudopleuronectes americanus* | 3 | 1 | 1 | 2 | 3 | 1 | | | **11** |
| **Total** | | **1337** | **1112** | **850** | **135** | **3272** | **1846** | **158** | **22** | **8732** |

*species with commercial status in Maritimes Canada.

Table 6. Mean (±se) species-specific fish density (ind. per $m^2$) pooled across sites. Data represent calibrated YOY equivalent and are the data used for the production model (Wong and Dowd 2017).

| Common name | Scientific name | Rockweed bed | Bare sediment |
|---|---|---|---|
| American eel | *Anguilla rostrata* | 0.7132 ± 0.3282 | 0.0009 ± 0.0009 |
| American lobster | *Homarus americanus* | 0.0004 ± 0.0003 | 0.0004 ± 0.0004 |
| Atlantic cod | *Gadus morhua* | 0.0126 ± 0.0029 | 0.0007 ± 0.0004 |
| Atlantic herring | *Clupea harengus* | 0.0330 ± 0.0113 | 0 |
| Atlantic mackerel | *Scomber scombrus* | 0.0007 ± 0.0004 | <0.0001 ± <0.0001 |
| Atlantic silverside | *Menidia menidia* | 0.0077 ± 0.0048 | 0 |
| Atlantic tomcod | *Microgadus tomcod* | 0.0079 ± 0.0013 | 0.0009 ± 0.0004 |
| Cunner | *Tautogolabrus adspersus* | 0.0273 ± 0.0050 | 0.0012 ± 0.0004 |
| Fourspine stickleback | *Apeltes quadracus* | 0.5520 ± 0.1908 | 0 |
| Grass shrimp | *Palaemon sp.* | 0.0408 ± 0.0007 | 0 |
| Green crab | *Carcinus maenas* | 1.3713 ± 0.2068 | 0.9372 ± 0.1296 |
| Grubby sculpin | *Myoxocephalus aenaeus* | 0.0024 ± 0.0012 | 0.0017 ± 0.0014 |
| Jonah crab | *Cancer borealis* | 0.0034 ± 0.0019 | 0 |
| Mummichog | *Fundulus heteroclitus* | 0.2535 ± 0.2039 | 0 |
| Pipefish | *Syngnathus fuscus* | 0.0020 ± 0.0002 | 0.0003 ± 0.0003 |
| Pollock | *Pollachius virens* | 0.0001 ± 0.0001 | 0 |
| Rock crab | *Cancer irroratus* | 0.0006 ± 0.0005 | 0.0016 ± 0.0014 |
| Rock gunnel | *Pholis gunnellus* | 0.0092 ± 0.0045 | 0.0002 ± 0.0002 |
| Sand lance | *Ammodytes americanus* | 0.3276 ± 0.1014 | 0.0051 ± 0.0033 |
| Smelt | *Osmerus mordax* | 0.0200 ± 0.0176 | <0.0001 ± <0.0001 |
| Threespine stickleback | *Gasterosteus aculeatus* | 0.0008 ± 0.0007 | 0 |
| White hake | *Urophysis tenuis* | 0.0002 ± 0.0001 | 0 |
| Winter flounder | *Pseudopleuronectes americanus* | 0.0019 ± 0.0010 | 0.0007 ± 0.0004 |

Figure 1. A. Northeastern US and the Canadian Maritimes with Nova Scotia (NS) indicated by the box. B. Field sites on the Atlantic coast of NS (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point, TR = Thomas Raddall). C. Photograph of East Jeddore site at low tide. Fyke net is visible in the background. D. Underwater photograph of A*scophyllum nodosum* bed at East Jeddore (August 3, 2016).



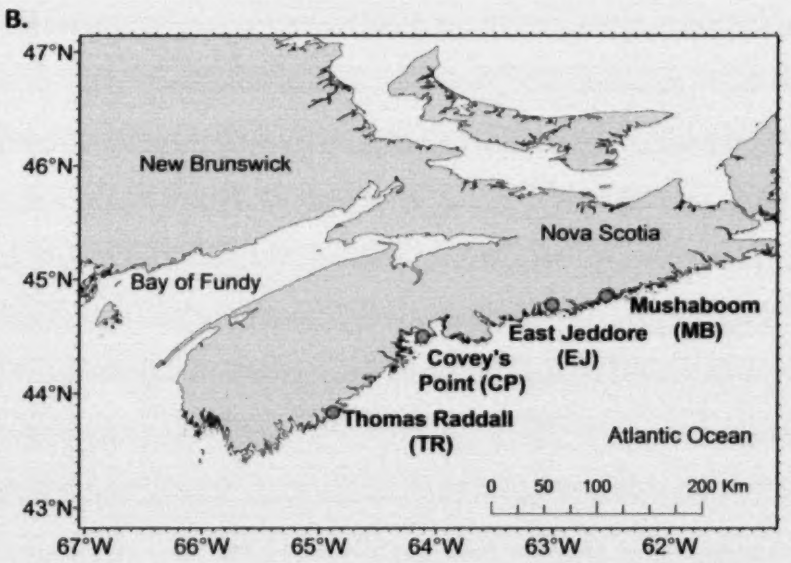



Figure 2. A. Fyke net deployed at low tide, and B. Submerged fyke net at high tide, at East Jeddore.

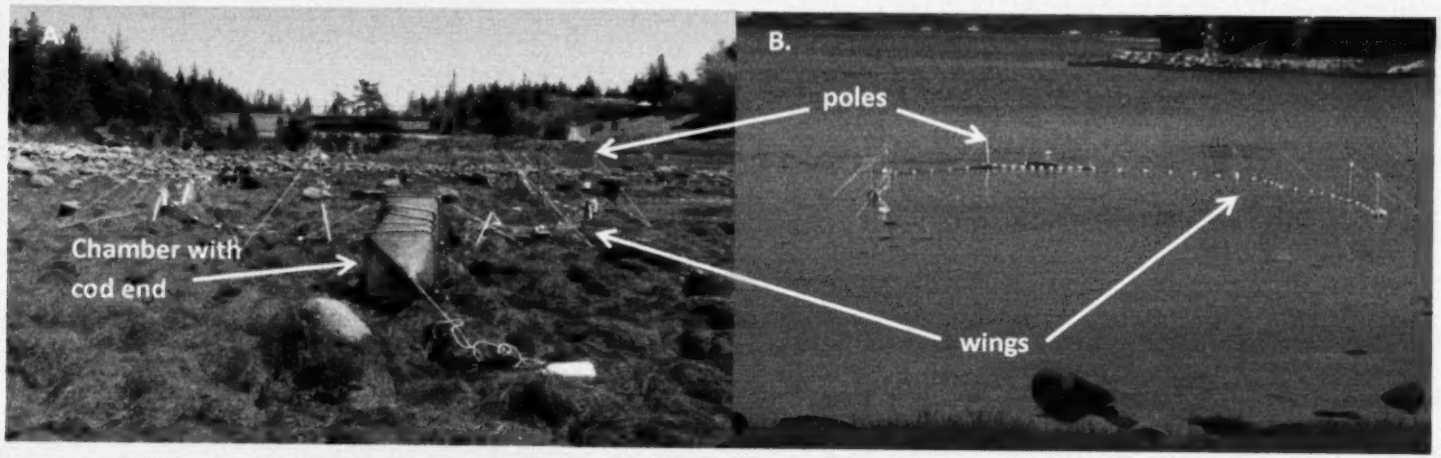



Figure 3. Average monthly temperature (±SD) at each field site in 2015 and 2016. The months of May and October were only partially monitored (start and end dates shown on the x-axes).

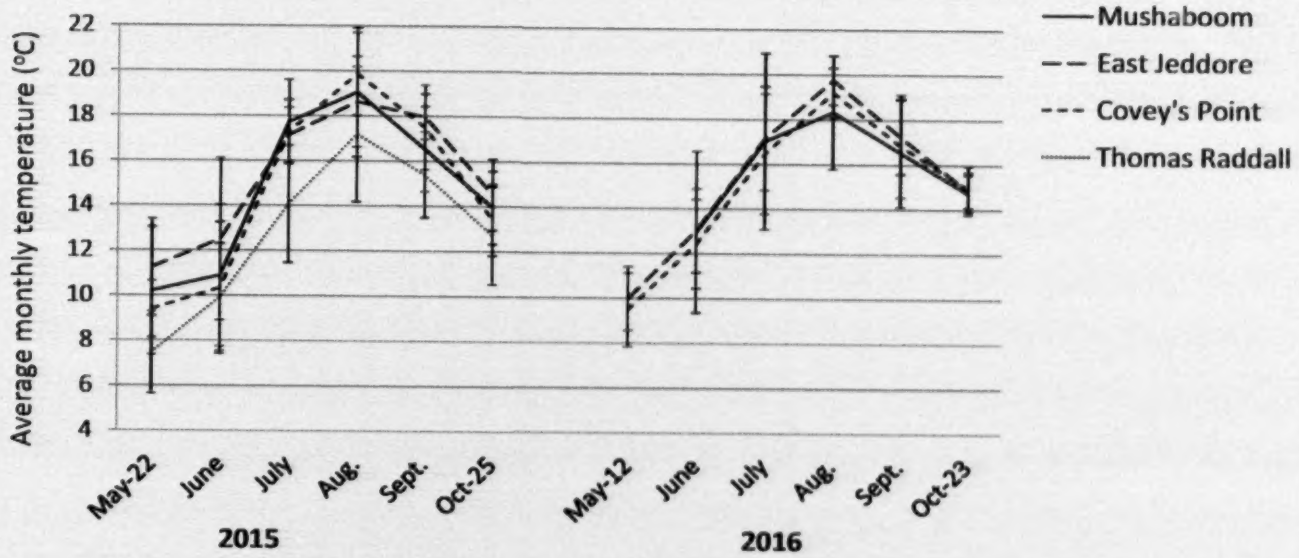


Figure 4. A. Mean height (±se) of *Ascophyllum nodosum* canopy at each field site (number of replicates in brackets), B. Mean total percent cover of vegetation (±se) per 0.5 m x 0.5 m quadrat. Note that percent cover was determined for the entire quadrat and some species overlaid others, so total percent cover may be greater than 100%, C. Total mean vegetation wet biomass (±se), and D. Total mean vegetation dry biomass (±se). (MB = Mushaboom, EJ = East Jeddore, CP= Covey's Point, TR = Thomas Raddall).

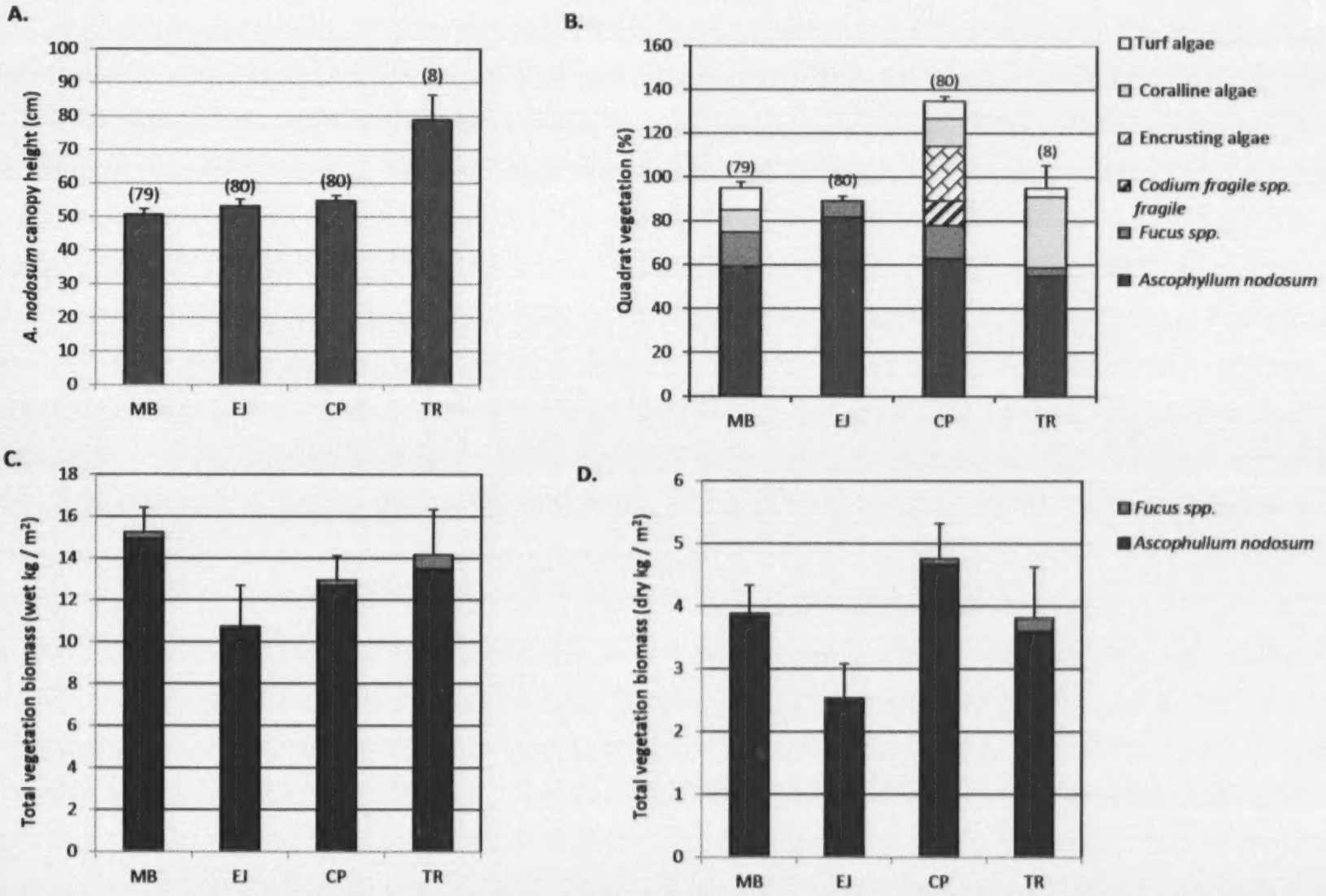


Figure 5. Size frequency histograms of fish species pooled across all sites, habitats and years. Size (mm) represents total or carapace length.

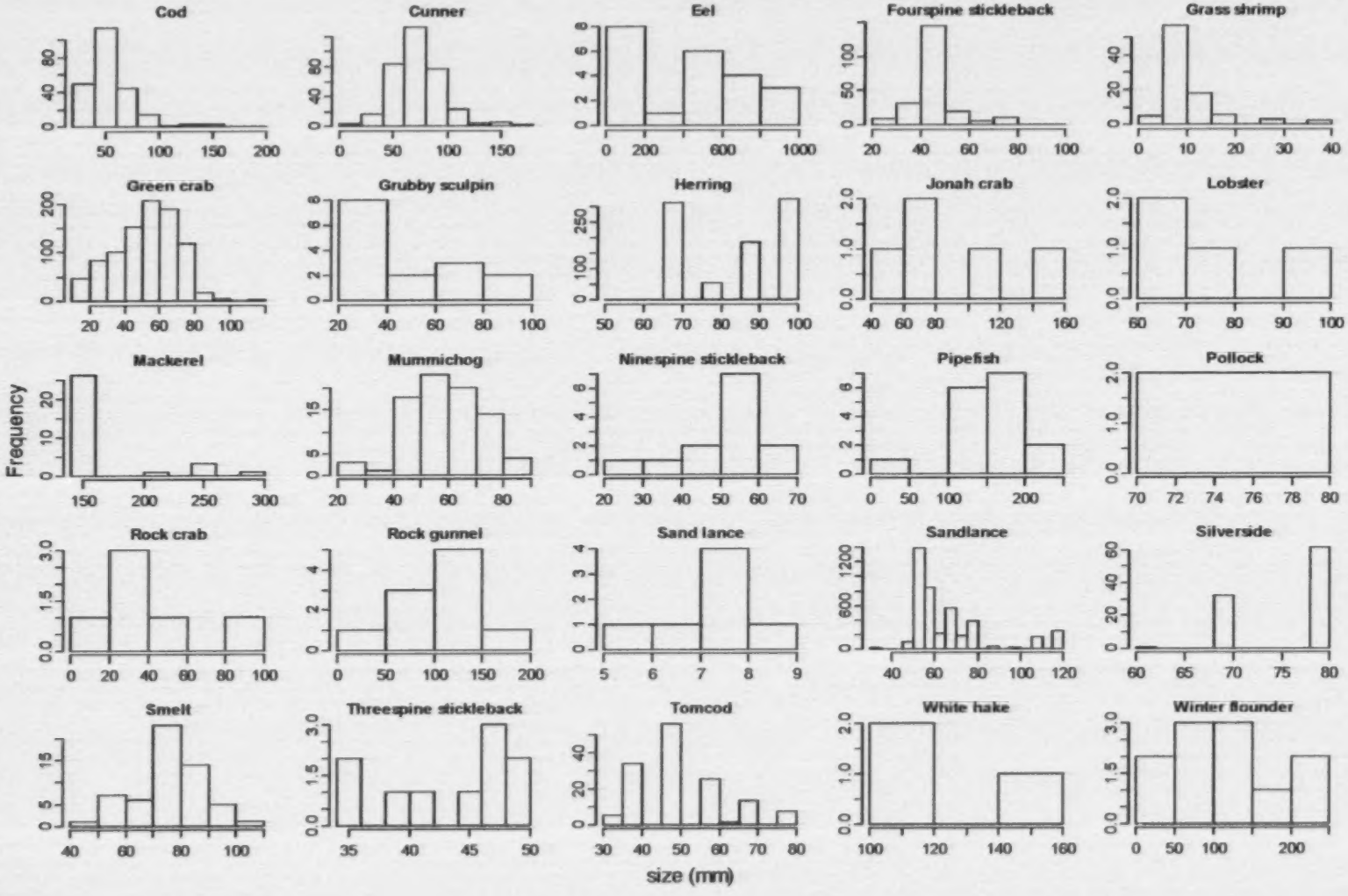


Figure 6. Fish density estimated from the fyke net and snorkel transects during the calibration exercise conducted at East Jeddore in July-August 2016. These data were used to determine appropriate calibration ratios to account for visual detection limitations during the visual surveys. Species with no bars represents zero density.

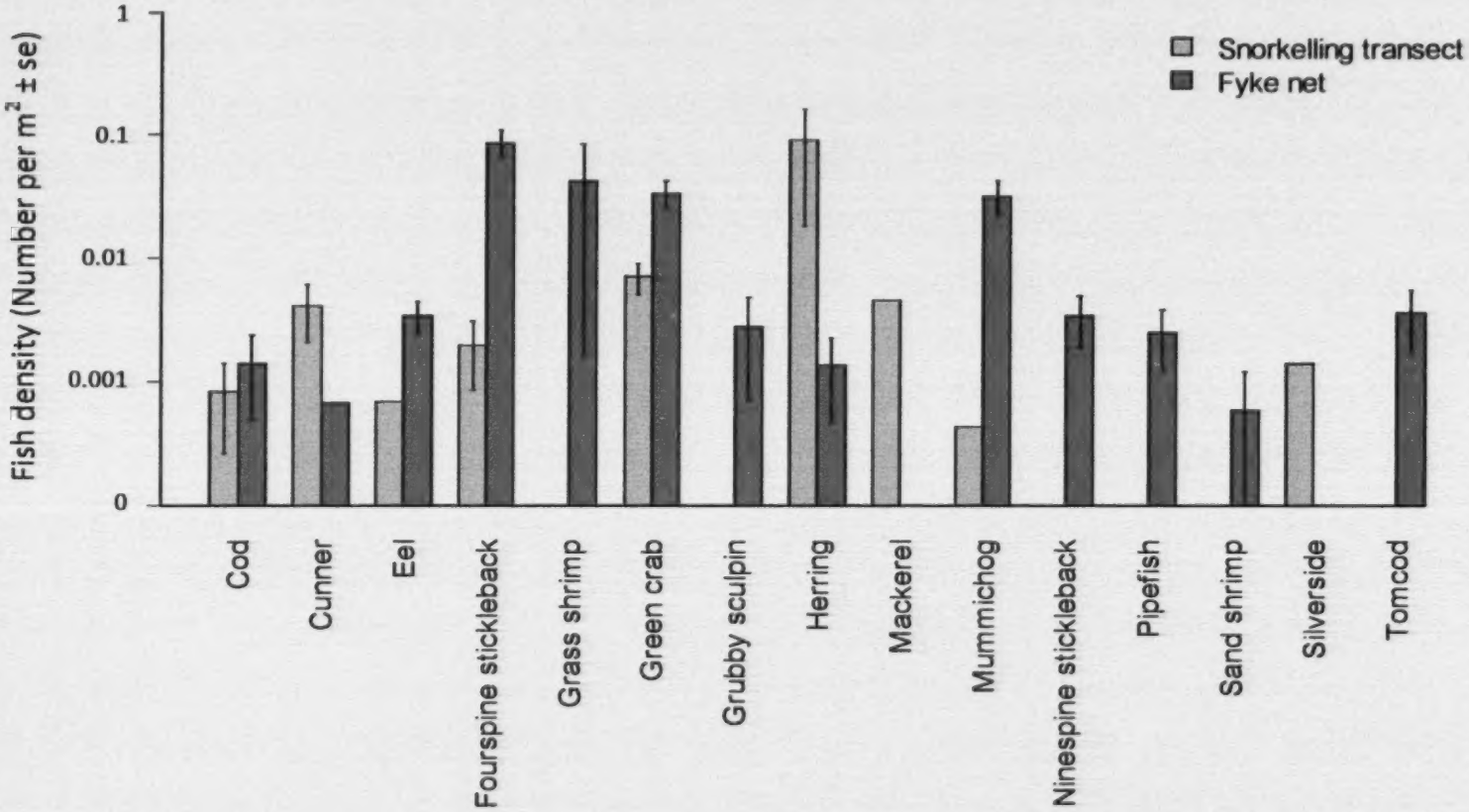


Figure 7. A. Species richness and B. Diversity in rockweed beds and bare sediments at each field site (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point, TR = Thomas Raddall) in each habitat type. Data are gear calibrated and pooled across years.

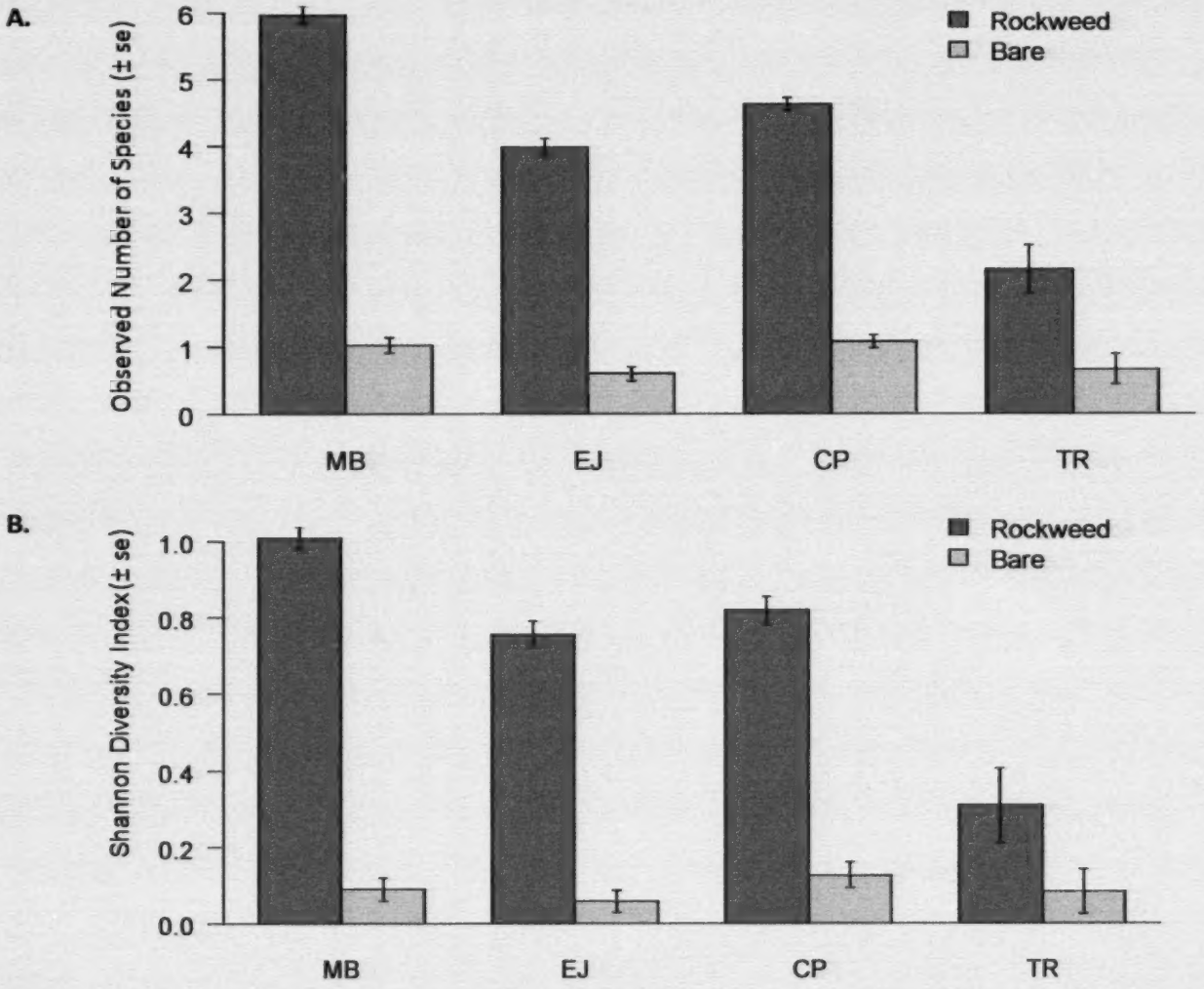


Figure 8. Mean gear calibrated fish-density (±se) of the 23 species detected in rockweed beds and bare sediments at NS field sites (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point, TR = Thomas Raddall). Data are pooled across years and are gear calibrated to account for limitations on visual detection during snorkel transects. Sites or habitats with no bars represent zero density of that species.

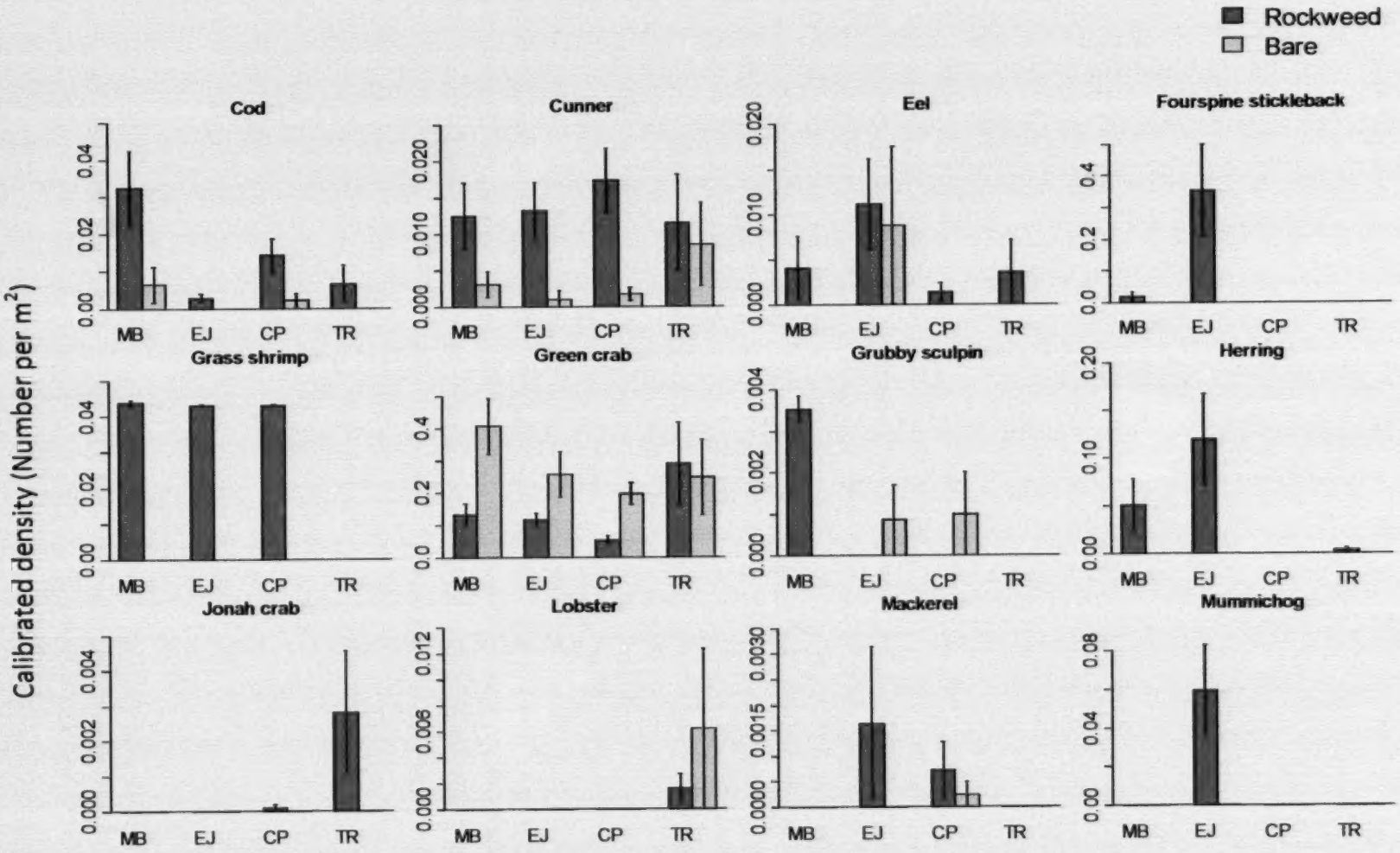


Figure 8. Continued. Mean gear calibrated fish-density (±se) of the 23 species detected in rockweed beds and bare sediments at NS field sites (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point, TR = Thomas Raddall). Data are pooled across years and are gear calibrated to account for limitations on visual detection during snorkel transects. Sites or habitats with no bars represent zero density of that species.

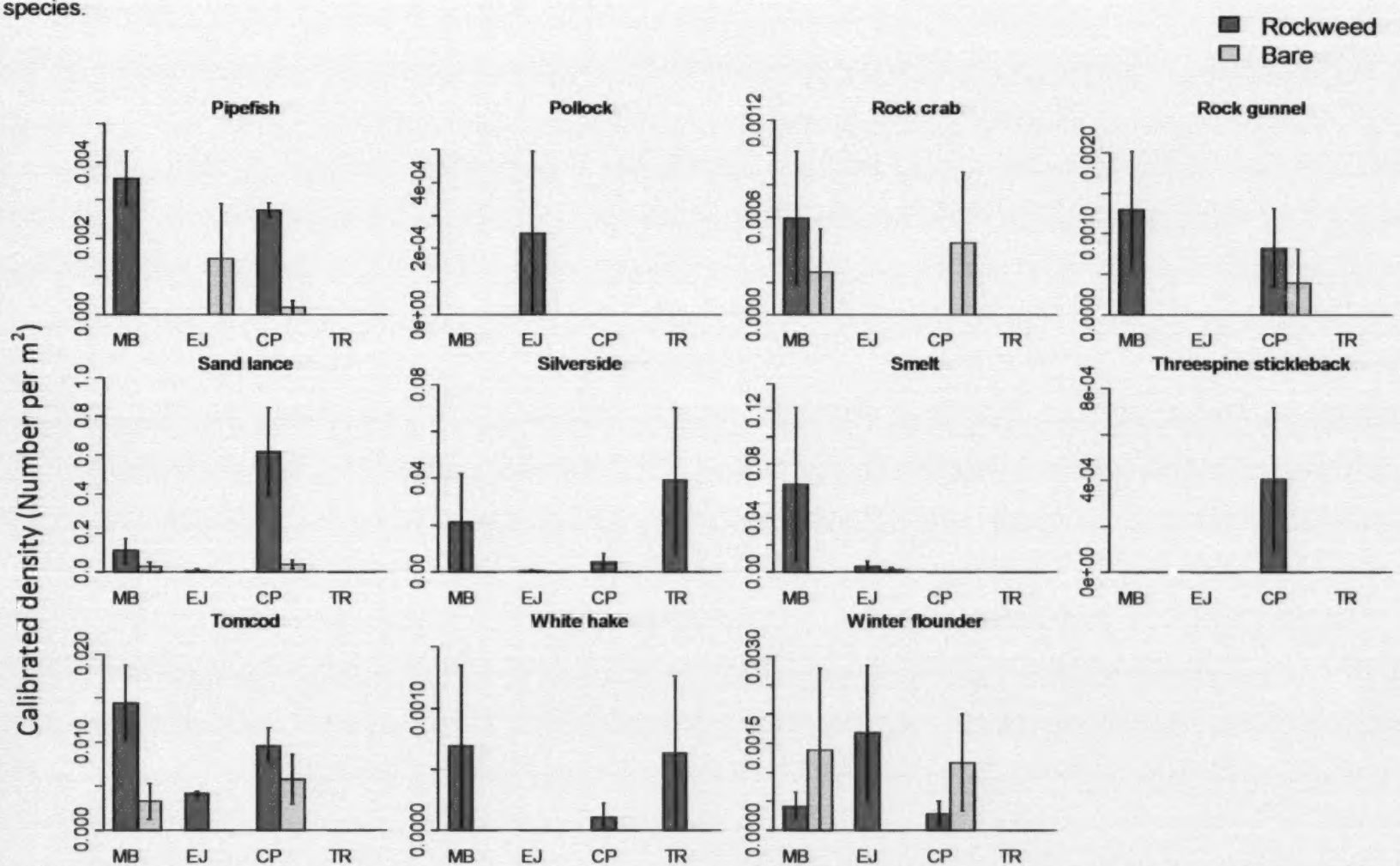


Figure 9. Mean gear calibrated fish-density (±se) at field sites (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point) in 2015 and 2016 in rockweed beds. Data are calibrated to account for limitations due to visual detection during snorkel surveys. Note that Thomas Raddall was not sampled in 2016. Sites with no bars represent zero density of that species.

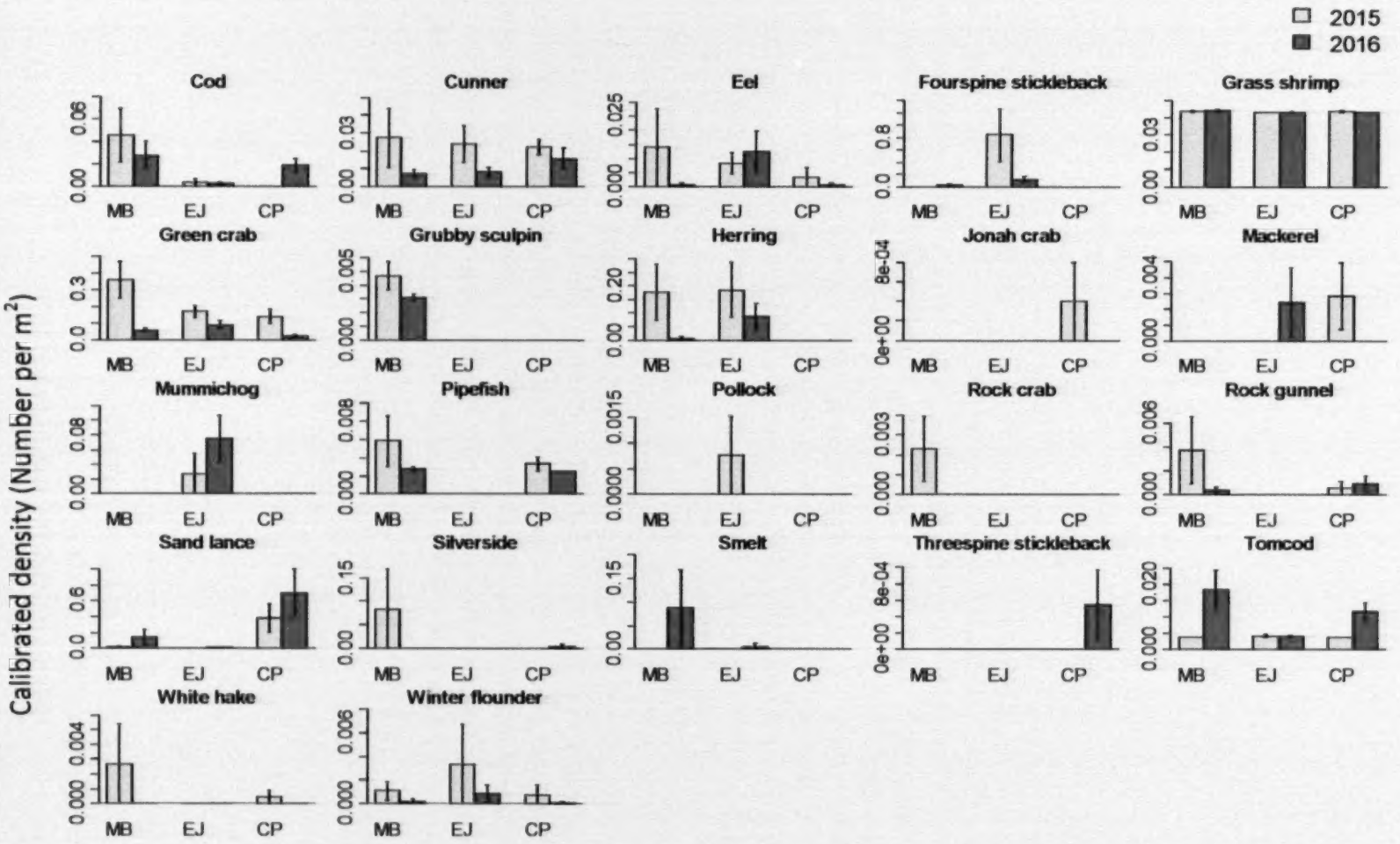


Figure 10. Monthly gear calibrated fish species specific densities (±se) in 2016 per site (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point) in rockweed habitat. Data are calibrated to account for gear underestimation during visual transects. Note that, out of 23 species, five (Jonah crab, Lobster, Pollock, Rock crab and White hake) are not displayed as their density was zero. Sites with no bars represented zero density of that species.

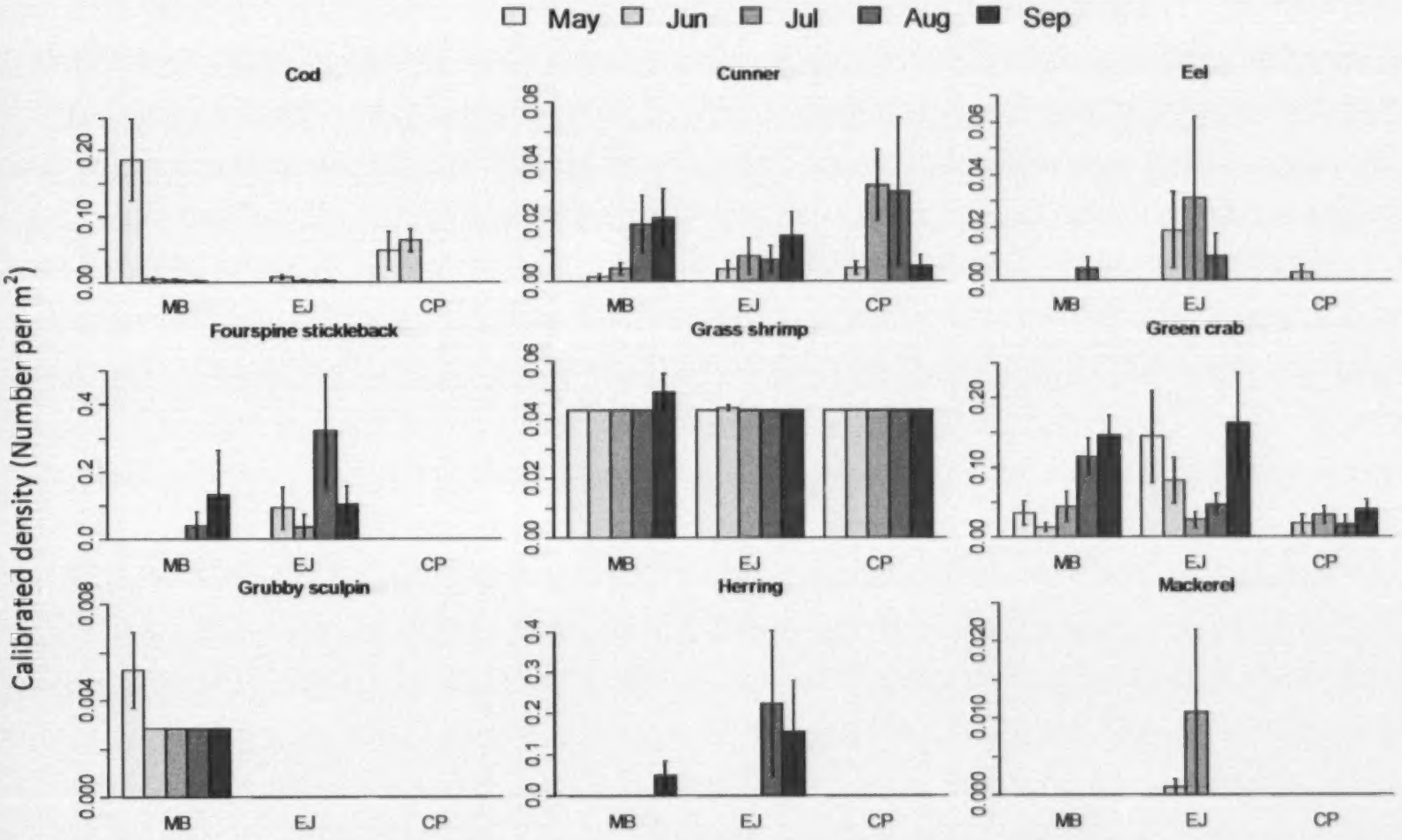
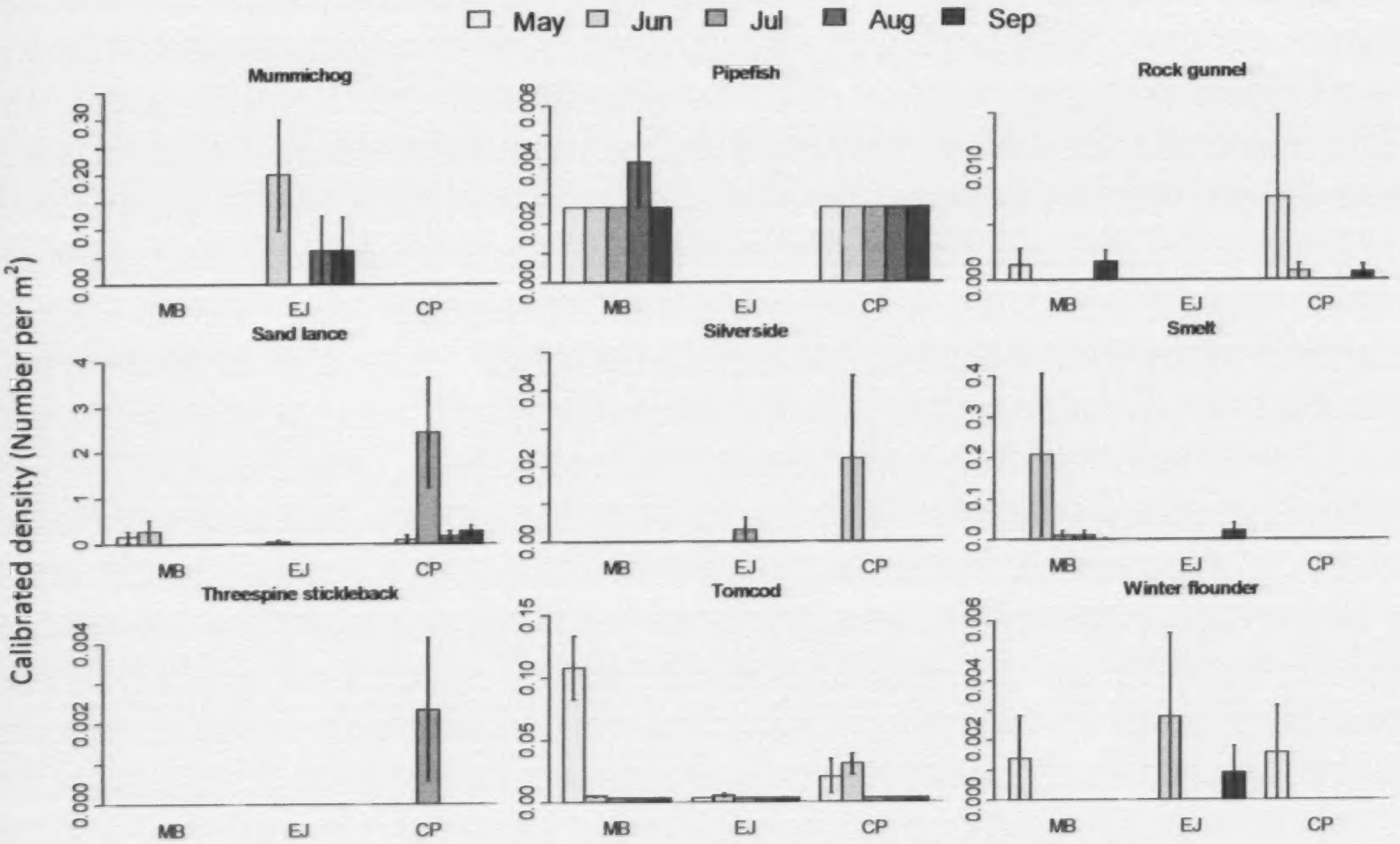
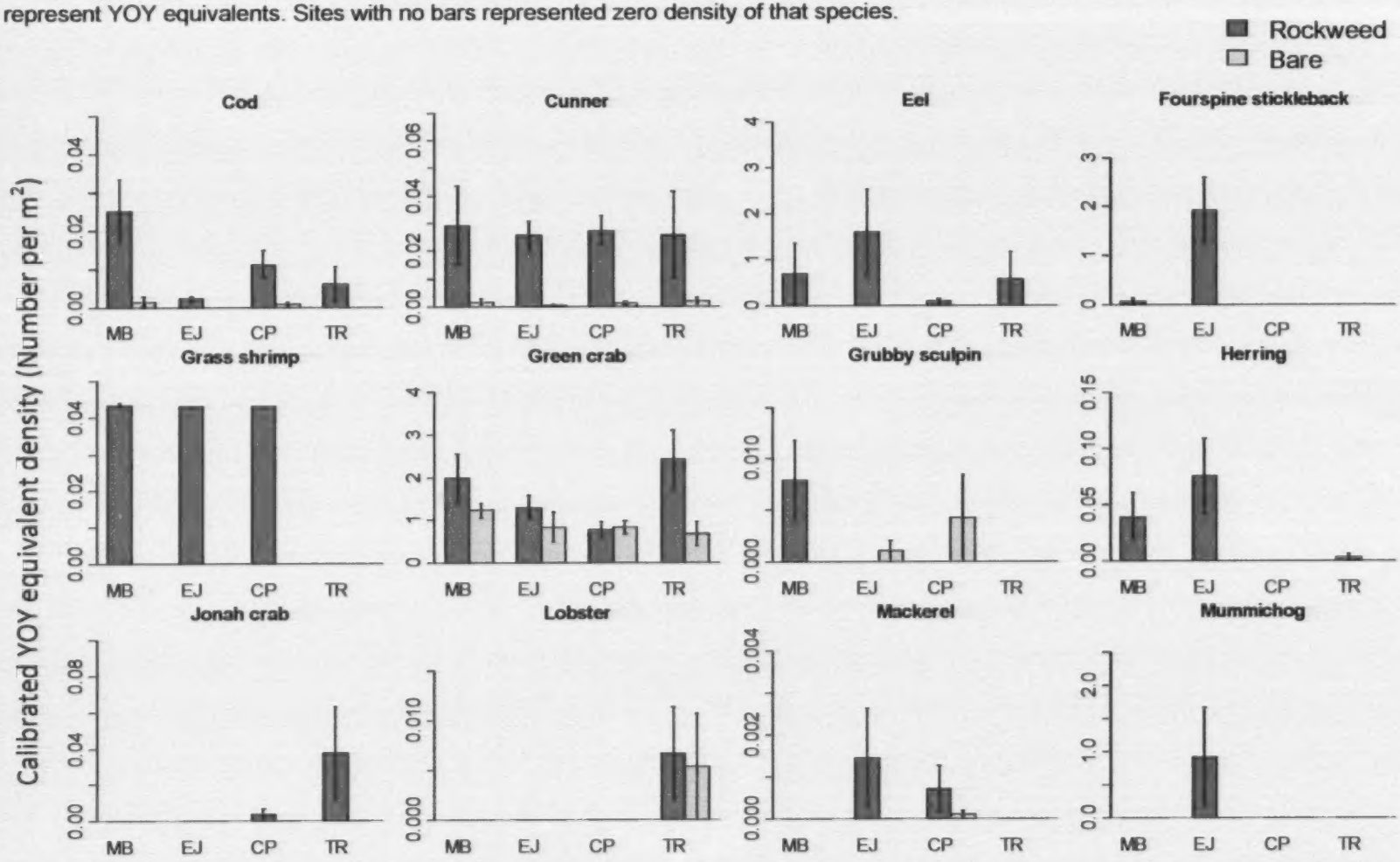


Figure 10. Continued. Monthly gear calibrated fish species specific densities (±se) in 2016 per site (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point) in rockweed habitat. Data are calibrated to account for gear underestimation during visual transects. Note that, out of 23 species, five (Jonah crab, Lobster, Pollock, Rock crab and White hake) are not displayed as their density was zero. Sites with no bars represented zero density of that species.



## Appendix

Mean calibrated fish-density (±se) in rockweed beds and bare sediments at field sites (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point, TR = Thomas Raddall). Data are pooled across years, gear calibrated to account for underestimation during visual transects and represent YOY equivalents. Sites with no bars represented zero density of that species.



Appendix. Continued. Mean calibrated fish-density (±se) in rockweed beds and bare sediments at field sites (MB = Mushaboom, EJ = East Jeddore, CP = Covey's Point, TR = Thomas Raddall). Data are pooled across years, gear calibrated to account for underestimation during visual transects and represent YOY equivalents. Sites with no bars represented zero density of that species.